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(54) **Turbine flowmeters**

(57) A flowmeter, suitable for measurement of fuel flow to engines, or of liquid to crop-spraying apparatus, having a bore within a body 20 with axially disposed parts, a bladed rotor element 21, 22 in the bore, the blades 21 having a higher reflective coefficient than the hub 22 upon which they are supported, a light source 26 with an associated photo-responsive device 27 arranged so that the light directed upon the rotor via optical guide means 18 or a lens system, is reflected more strongly from the rotor blades 21 than from the hub 22 so producing an electrical out-put signal with a frequency component proportional to the speed of rotation of the rotor.

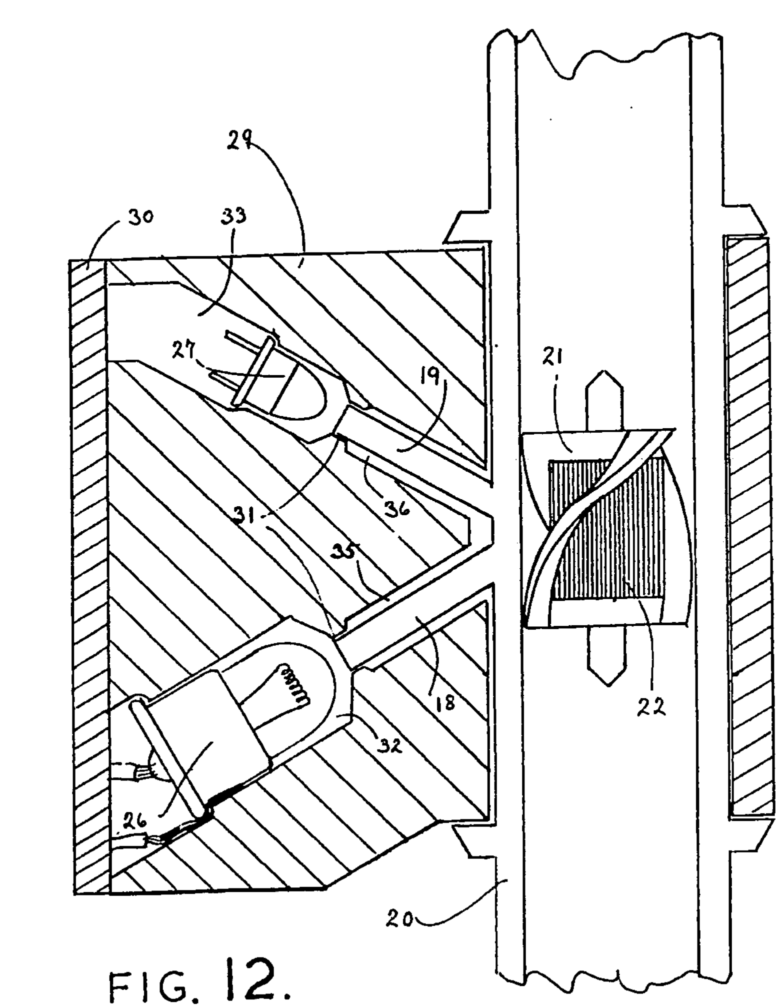

FIG. 12.

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

SPECIFICATION

Improvements in or relating to flowmeters

This invention relates to flowmeters.

A flowmeter suitable for measuring the rate of supply of fuel to a petrol engine or the rate of supply of spraying liquid to the boom of agricultural or horticultural spraying equipment includes a bladed rotor element which is rotated by liquid passing through the meter, the speed of rotation being proportional to the rate of flow. Such flowmeters may be required to operate over a range of flow rates from 0.25 to 30 gallons per hour. The lower end of the range dictates that the maximum diameter of the bore in which the rotor element is mounted should be generally less than 0.25 inches.

At low flow rates there is an unacceptable drag effect if an electromagnetic device is used for sensing the speed of rotation of the rotor element. Although an inductive sensor overcomes this problem, the element must be made of metal, or must include a metallic insert. It is then costly to manufacture the element from a metal which is corrosion resistant and the element is heavy, which means higher bearing friction and hence poor flow rate characteristics. It is preferable therefore to make the rotor element of a plastics material, which offers the advantage of low cost, low weight, low production spread in terms of dimensional accuracy, and a choice of materials which have suitable chemical and physical propertires.

To detect the speed of rotation of the rotor element an optical sensing device has been proposed as an alternative to an inductive or electromagnetic device. In the optical device a beam of light is transmitted across the bore so that it is interrupted by the rotating blades of the rotor element. A photodetector to which the beam is applied generates an electrical signal of frequency representing the frequency at which the beam is interrupted, and hence the speed at which the element is rotated. For satisfactory operation, this optical device relies upon a high degree of transparency of the liquid passing through the meter. Further, spurious signals are produced if the liquid includes gas bubbles which interrupt the light beam. It is found that there may be errors of up to 25%, particularly if the "lens effect" of liquid within the bore is used to focus the light beam on to the photodetector.

According to the present invention there is provided a flowmeter wherein a bladed rotor element is mounted in a bore formed in a body so that fluid flowing through the bore causes the element to rotate at a speed representative of the rate of flow of fluid, means are provided for directing electromagnetic radiation into the bore and towards the rotor element so that a radially outer face of at least one rotor blade moves across the path of the radiation during each rotation of the element, and means are provided for detecting radiation relfected by the said face of the or each blade and generating an electrical signal having an electrical parameter which varies in a manner representative of the variation in intensity of the reflected radiation, and hence a representative of the speed of rotation of the rotor element.

Preferably, the part of the or each blade from which radiation is reflected to the detecting means has a higher coefficient of reflection than a hub upon which the blade or blades is supported.

Suitably, the said part of the or each blade is adjacent to a side wall through which the radiation enters the bore during the time within which radiation is reflected therefrom, whereby the radiation travels only a short distance through fluid flowing through the bore.

The means for directing radiation into the bore may comprise an elongated guide member of a material having a refractive index greater that the refractive index of the medium in which the member is disposed. The guide member may then comprise a rod of glass or plastics material or an optical fibre.

The means for detecting reflected radiation may comprise a detector and means for directing reflected radiation to the detector. The directing means may comprise an elongated guide member of a material having a refractive index greater than the refractive index of the medium in which the member is disposed. The guide member may then comprise a rod of glass or plastics material or an optical fibre.

There may be provided a generally Y-shaped member so arranged that one limb and the body of the member serve as the means for directing radiation into the bore, and the body and the other limb of the member serve to direct reflected radiation to a detector.

The means for directing radiation into the bore and a means for directing reflected radiaton to a detector may be formed integrally with the body in which the bore is formed. Suitably, the body is tubular.

The means for directing radiation into the bore and/or the means for directing reflected radiation to a detector may comprise an elongated optical fibre, whereby a source of the said radiation and/or a detector of the reflected radiation can be disposed remotely of the rotor element.

The electromagnetic radiation is suitably visible radiation.

A further difficulty in designing a satisfactory flowmeter, particularly a flowmeter for use in a fuel supply system, is that flow conditions are often erratic.

According to the invention, there is also provided a flowmeter wherein a bladed rotor element is mounted in a bore formed in a body so that fluid flowing through the bore causes the element to rotate at a speed representative of the rate of flow of fluid, means are provided for sensing the speed of rotation of the rotor element, a bypass chamber has an inlet connected to the bore at a location upstream of the rotor element and an outlet connected to the bore at a location downstream of the element, and a valve member is slidable within the bypass chamber, the valve member being so arranged that if the pressure applied to fluid upstream of the inlet to the chamber is such as to produce a constant rate of flow of the fluid or is increased, the member is urged in a direction downstream of the chamber and

serves to close or partially close the outlet therefrom, whilst if the said pressure is reduced, the member is urged in a direction upstream of the chamber so that fluid can flow through the chamber in a direction from the outlet towards the inlet thereof.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is an axial section of a rotor element in a flowmeter according to the invention;

Figure 2 is a side elevation of a modified form of the element of Figure 1.

Figures 3 to *6, 9* to *11* and *13* are diagrammatic side elevations of flowmeters according to the invention;

Figures 7 and *8* are transverse sections of further flowmeters according to the invention;

Figure 12 is an axial section of a further flowmeter according to the invention;

Figure 14 is a diagrammatic side elevation of a flowmeter according to the invention which includes a bypass chamber;

Figure 15 is a transverse section of the bypass chamber in the flowmeter of Figure 14;

Figure 16 is a transverse section of an alternative bypass chamber for the flowmeter of Figure 14; and

Figure 17 is a diagrammatic side elevation of a bypass chamber in a further flowmeter according to the invention.

The flowmeters shown in Figures 3 to 17 of the drawings are suitable for use in measuring the rate of supply of fuel to a petrol engine or the rate of supply of spraying liquid to a boom in agricultural or horticultural spraying equipment. Each of these flowmeters includes a tubular body which, in use, is connected into a line along which the fuel or spraying liquid is passed. Within the bore of the body is a bladed rotor element so arranged that liquid flowing through the bore causes the element to rotate at a speed proportional to the rate of flow of liquid. For measuring the speed of rotation, a light source is mounted outside the body and guide means are arranged to direct a beam of light from the source into the bore so that a radially outer face of each blade on the rotor element moves across the beam once during each rotation of the element. Light reflected from the radially outer face of each blade is directed by further guide means to a photosensitive detector, which produces an electrical output signal whose frequency is proportional to the speed of rotation, and hence proportional to the rate of flow of liquid.

Figure 1 shows a rotor element which is included in each of the flowmeters of Figures 3 to 13. The element includes a hub 1 which is moulded from a plastics material having a low coefficient of reflection, preferably black material. Supported by the hub are three helical blades 2 of a plastics material having a high coefficient of reflection, preferably a white plastics material or a plastics material impregnated with a reflective substance to produce a highly reflective surface.

To manufacture the rotor element of Figure 1, the hub 1 is first moulded from suitable plastics material. The hub 1 has an overall length which is some 20 to 30% shorter than the overall length which is desired for the rotor element. One end of the hub 1 has a reduced diameter so that a shoulder is formed between an end section and the main part of the hub. The hub can also be formed with a shoulder at each end, in which case its overall length is the same as that of a rotor.

The hub 1 is then transferred to a second mould which has a core pin of the same diameter as a bore 3 in the hub, the hub being positioned precisely by the closure of the mould against an end face 5 of the hub. A white or impregnated plastics material is then injected into the second mould to produce the blades 2.

In the modified form of rotor element shown in Figure 2, a hub 22 and three helical blades 21 are moulded from a black plastics material having a low coefficient of reflection, and a disc or pad 34 is provided on each blade. The three discs or pads 34 have a common axial location.

The rotor element of Figure 2 is made by a single moulding operation. An injection moulding tool for producing this moulding includes cavities into which three discs or pads 34 can be loaded before each moulding operation and movable cores for pressing respective discs or pads into place towards the end of each operation.

Referring now to Figure 3 of the drawings, a first embodiment of the invention includes a rotor element 21, 22 which is mounted within the bore of a tubular body 20. The element 21, 22 has the form of the element shown in Figure 1 or 2 and is disposed coaxially of the bore. The body 20 is made of glass or transparent plastics material or of opaque material into which at least one window is fitted.

In the embodiment of Figure 3 the core of the element 21, 22 has an external diameter of 0.14 inches and each of the blades has a radial length of 0.045 inches. There is a spacing of 0.006 inches between a radially outer face of each blade and the wall of the bore in the body 20.

A light source 26 is mounted a short distance away from the body 20 and a light guide 18 is arranged to direct a beam of light from the source 26 into the bore of the body 20 via its transparent side wall or window. The guide 18 is so arranged that a radially outer face of each blade on the element 21,22 moves across the beam of light from the source 26 once during each rotation of the element. A further light guide 19 is arranged to receive light reflected by the radially outer face of each blade as it moves across the beam and to direct the light on to a photosensitive detector 27.

In the embodiment of Figure 3, each of the guides 18 and 19 is a transparent rod of plastics material which is approximately 1 mm diameter. The rods 18 and 19 are mounted so that their axes lie in a plane which includes the axis of the rotor element 21, 22 and the body 20.

When the flowmeter of Figure 3 is in use, liquid flowing through the bore of the tubular body 20 impinges against the blades 21 of the element 21, 22 and causes the element to rotate. The speed of rotation is proportional to the rate of flow of liquid

along the bore. A beam of light from the source 26 is directed into the bore of the body 20 by the light guide 18 and is reflected into the further guide 19 and on to the detector 27 each time one of the blades 21 moves across the beam, i.e. three times per revolution of the element 21, 22. The detector 27 produces an electrical output signal which varies periodically at a frequency equal to the frequency at which pulses of radiation are applied thereto. The signal is applied via suitable circuits in the case of a simple flowrate indicator to a meter which gives a reading representative of the frequency of the output signal, and hence representative of the speed of rotation of the body 20, 21 and the rate of flow of the liquid along the bore.

In modifications of the flowmeter of Figure 3 the light guides 18 and 19 are polymerised plastics optical guides of about 1 mm diameter or glass fibre optical guides of about 0.1 mm diameter or bundles of glass fibre optical guides.

Figure 4 is a second embodiment of the invention which has a tubular body 20, a rotor element 21, 22, a light source 26 and a photosensitive detector 27 of the form shown in Figure 3. In the flowmeter of Figure 4, however, a Y-shaped light guide 28 replaces the guides 18 and 19 of Figure 3. This guide 28 is arranged so that light from the source 26 travels along one limb and the body of the "Y" and enters the bore of the body 20 in a radial direction. Light reflected from the radially outer face of each blade 21 on the rotor element 21, 22 reenters the body of the guide 28 and a part of this light then travels via a second limb of the "Y" to the detector 27.

The guide 28 of Figure 4 is moulded from transparent plastics material. The included angle between the two limbs of the "Y" is less than half the critical angle of the material in air so that light from the source 26 does not enter the second limb and interfere with the reflected light. Light can be directed accurately towards the element 21, 22 by means of the guide 28.

Figure 5 is an embodiment corresponding to the embodiment of Figure 3 except that the light guides 18 and 19 are formed integrally with the tubular body 20. The guides 18 and 19 and the body 20 are in this embodiment moulded from transparent plastics material. Figure 6 is a further embodiment corresponding to the embodiment of Figure 4 but having a Y-shaped guide 28 formed integrally with the body 20.

Figure 7 is a section at right angles to the axis of a further flowmeter according to the invention which has a rotor element 21, 22 and a tubular body of the form shown in previous embodiments. Moreover, there are again light guides 18 and 19 which are formed integrally with the body 20. In the flowmeter of Figure 7, however, the axes of the guides 18 and 19 lie in a plane which is perpendicular to the axes of the rotor element 21, 22 and the body 20.

Marked in Figure 7 are the paths of rays of light which are incident upon the rotor element 21, 22 and which are reflected therefrom at various angular positions of the element. First, there is a divergent cone of rays which emerges from the guide 18 and impinges upon the radially outer face of a blade 21 when the element 20, 21 is in the angular position shown in Figure 7. The periphery of the cone is indicated by the points A and B. Light reflected from the blade 21 diverges further and illuminates a generally circular area of the outer surface of the body 20, designated by the points C and D in Figure 7. Part of this reflected light enters the guide 19 and is directed towards the detector 27.

When the element 21, 22 has rotated from the position shown in Figure 7, light from the guide 18 impinges upon the hub 22 of the element 21, 22, illuminating an area of the hub whose periphery is indicated by the points F and L. From the hub the light is reflected on to an area of the body 20 extending angularly between the points I and K. The arc IH is approximately 205° whilst the arc CD is only approximately 18°. There is therefore a ratio of approximately 11:1 between the area of the body 20 illuminated by the reflected light when the element 21, 22 is in the angular position shown in Figure 7 and the area illuminated when the element 21, 22 has been rotated from this position.

Figure 8 is an embodiment of the invention wherein the guides 18 and 19 of Figure 7 are replaced by a Y-shaped guide 23 corresponding to the guide 28 of Figure 6. The guide 23 is formed integrally with the body 20 and is arranged with the axes of the body and limbs 24 and 25 thereof disposed in a plane perpendicular to the axis of the body 20 and the rotor 21, 22.

Figure 9 is an embodiment suitable for use with a tubular body 20 and rotor element 21, 22 thereof at an ambient temperature greater than the temperature at which a photosensitive detector 27 can be operated. In this embodiment the detector 27 is located remotely of the body 20 and the rotor element 21, 22 and light reflected from the element 21, 22 is guided to the detector by means of a single or double, plastics or glass optical guide of extended length, say 50 inches long.

Figures 10 and 11 show further embodiments which can be used with both the detector 27 and the light source 26 remote from the rotor element 21, 22 and the body 20. In Figure 10 there is a single extended light guide 19 which is connected to a Y-shaped guide 28. In the embodiment of Figure 11 there is an extended light guide 18 for directing light from the source 26 to the element 21, 22 and a further extended guide 19 for directing reflected light to the detector 27.

Figure 12 is an embodiment corresponding to the embodiment shown in Figure 5 in that a pair of light guides 18 and 19 are moulded integrally with a tubular body 20, the axes of the guides lying in a plane which includes the axis of the body 20 and a rotor element 21, 22. In the embodiment of Figure 12, however, a body 29 of opaque material houses a light source 26 and a photosensitive detector 27 and also receives a pair of light guides 18 and 19.

Referring to Figure 12, the body 29 is formed with cavities 32 and 33 for housing the source 26 and the detector 27, respectively, and with channels 35 and 36 for receiving respective light guides 18 and 19. An inner section 31 of the channel 35 has a reduced diameter which is only slightly larger than the

diameter of the guide 18 so that no light from the source 26 can reach the element 21, 22 unless it has travelled via the guide 18. Similarly, an inner section 31 of the channel 36 has a reduced diameter for preventing reflected light other than light which travels along the guide 19 from reaching the detector 27.

In the embodiments described above the axes of the light guides are disposed in a plane which includes the axes of the body 20 or is perpendicular thereto. It will be appreciated that alternative arrangements can be employed. For example, the guides can be arranged with the axes of the guides lying in a plane which is inclined at 45° to the axis of the body 20.

As an alternative to the light guides of previous embodiments, lenses can be used for directing light from a source to a rotor element and for directing reflected light from the element to a photosensitive detector. Figure 13 is such an embodiment in which an aspheric lens 1 is used for directing light from a source 3 on to a rotor element and an aspheric lens 2 is used to direct reflected light on to a detector 4.

It will be appreciated that a rotor element having a hub and a plurality of radially extending blades can be used in place of the elements 21, 22 with helical blades describes above. The tubular body 20 can be made of opaque material having glass or plastics windows through which light is directed on to the rotor element. Infra-red or untraviolet radiation can be used instead of visible radiation.

In Figures 14 and 15 of the drawings there is shown a flowmeter according to the invention which is particularly suitable for use in automotive fuel systems. The flowmeter is designed to reduce the effect of pump pulsations, fuel surges due to float needle behaviour and fluctuations caused by vapour bubbles in the fuel employed in such systems.

The flowmeter of Figures 14 and 15 includes a rotor element 6 corresponding to the rotor element 21, 22, above, and a body 9 corresponding to the tubular body 20, above. Also included, but not shown in the drawings, are a light source, optical guide means and a photo-sensitive detector, which are designed in accordance with any one of the embodiments described above.

Referring to Figure 14, the present flowmeter further includes a by-pass chamber 7 having an inlet 4 connected to the body 9 at a location upstream of the rotor element 6 and an outlet 5 connected to the body 9 at a location downstream of the element 6. As shown in Figure 15, the wall of the chamber 7 is formed with a series of very shallow ridges 8 which extend lengthwise of the chamber. At an inlet end of the chamber 7 there is a conical valve seat 10 and at an outlet end there is a conical valve seat 11.

Within the chamber 7 is a valve member in the form of a ball 1, which is made of a material having a specific gravity equal to or substantially equal to the specific gravity of the fuel in which it is immersed. This means that the ball does not float or sink if the flowmeter is arranged so that the axis of the chamber 7 is not horizontal. The ball has a diameter slightly smaller than the diameter of the generally cylindrical space which is located radially inwardly of the ridges 8, so that the ridges maintain the ball in a position centrally of the chamber 7, as viewed in Figure 15. The ball 1 is slidable in a direction longitudinally of the chamber 7.

When the present flowmeter is in use and the pressure applied by a pump upstream of the meter produces a constant or substantially constant flow rate, the ball 1 is urged in a downstream direction. This causes the ball 1 to engage the valve seat 11, reducing the flow of liquid through the chamber 7 to zero or to a very small amount. The speed of rotation of the element 6 then provides an accurate representation of the flow rate.

In practice, the pressure applied to the liquid by the pump will fluctuate, there being a rise in pressure on each delivery stroke of the pump and a reduction in pressure upon each return stroke.

During each delivery stroke, the ball 1 moves into engagement with the valve seat 11 and liquid within the bore of the body 9, and any vapour within the liquid, is subjected to a relatively high pressure. At the end of the delivery stroke the pressure applied by the pump is reduced and any vapour downstream of the element 6 is able to expand. The result of the expansion is that some of the liquid downstream of the element 6 is urged in an upstream direction, into the outlet 5 of the by-pass chamber 7. The ball 1 is therefore disengaged from the seat 11 and liquid is able to pass through the chamber 7 to the inlet 4, which is upstream of the element 6. This transfer of liquid offsets all or part of the reduction in supply of liquid from the pump.

When the return stroke of the pump has been completed, the pump commences a new delivery stroke and the pressure applied to the liquid again rises. The ball 1 is forced along the chamber towards the seat 11, though some liquid is also able to flow past the ball, between the ridges 8, until such time as the ball is again engaged with the seat. The movement of this liquid past the ball and the movement of a volume of liquid displaced by the ball has the effect of reducing the pressure difference between the inlet and the outlet to the chamber 7, sensing to even out fluctuations in pressure.

It will be appreciated that there is some leakage through the by-pass chamber 7 at low rates of flow, when the pressure applied to the liquid may not be sufficient to cause the ball 1 to engage the seat 11. However, it is at low flow rates that there is the greatest tendency for the flowmeter to "over-read" during conditions of fluctuating pressure, since a very low rate of rotation can, in some circumstances permit the rotor element to oscillate to and fro in response to pulsations in the output pressure of the pump.

Typical values of the pressure pulses from a pump may be sufficient to give peak flow rates of 6 to 10 gallons per hour even though the average flow rate is only $\frac{1}{2}$ gallons per hour. These high pressure pulses mean that the ball 1 slides to and fro in the chamber 1, even under conditions of low average flow rate.

Figure 16 of the drawings is a transverse section of an alternative embodiment in which there are no ridges 8. The diameter of the ball 1 is then only

slightly smaller than the internal diameter of the bore in the body 9.

In Figure 17 there is shown an alternative meter in which a spring 12 serves to urge the ball 1 in an upstream direction. The action of the spring assists the return flow of liquid from the outlet 5, through the chamber 7 towards the inlet 4. This is desirable since the output pressure from the pump on the delivery stroke is higher than the reverse pressure described above.

CLAIMS

1. A flowmeter comprising a bladed rotor element mounted in a bore formed in a body so that fluid flowing through the bore causes the element to rotate at a speed representative of the rate of flow of fluid, means are provided for directing electromagnetic radiation into the bore and towards the rotor element so that a radially outer face of at least one rotor blade moves across the path of the radiation during each rotation of the element, and means are provided for detecting radiation reflected by the said face of the or each blade and generating an electrical signal having an electrical parameter which varies in a manner representative of the variation in intensity of the reflected radiation, and hence representative of the speed of rotation of the rotor element.

2. A flowmeter according to claim 1, wherein the part of the or each blade from which radiation is reflected to the detcting means has a higher coefficient of reflection than a hub upon which the blade or blades be supported, the said part of the or each blade is adjacent to a sidewall through which the radiation enters the bore during the time within which radiation is reflected therefrom, whereby the radiation travels only a short distance through fluid flowing through the bore.

3. A flowmeter according to claim 1 in which the means fo directing radiation into the bore and for directing reflected radiation to the detector may comprise an elongated guide member of a material having a refractive index greater than the refactive index of the medium in which the member is disposed. The guide member may suitably comprise a rod of plastics material, glass or an optical fibre.

4. A flowmeter according to claim 1 in which the means for directing radiation into the bore and/or the means for directing reflected radiation to a detector may be formed integrally with the body in which the bore is formed, the body being suitably of tubular shape.

5. A flowmeter according to claim 1 in which the means for directing radiation into the bore and/or the means for directing reflected radiation to a detector may comprise and elongated optical fibre, whereby a source of the said radiation and/or a detector of the reflected radiation can be disposed remotely of the rotor element.

6. A flowmeter according to claim 1 in which there is provided a generally Y-shaped member so arranged that one limb and the body of the member serve as the means for directing radiation into the bore and the body and the other limb of the member serve to direct reflected radiation to a detector.

7. A flowmeter as in claim 1 in which a lens system is used for directing radiation into the bore and for directing the reflected radiation onto a detector.

8. A flowmeter according to claim 1 in which the body is made of opaque material having glass or plastics windows through which radiation enters the bore and through which it is reflected to the detector.

9. A flowmeter as in all previous claims in which infra-red or ultra-violet radiation is used instead of visible radiation.

10. A flowmeter wherein a bladed rotor element is mounted in a bore formed in a body so that the fluid flowing through the bore causes the element to rotate at a speed representative of the rate of flow of fluid, means are provided for sensing the speed of rotation of the rotor element, a bypass chamber has an inlet connected to the bore at a location upstream of the rotor element and an outlet connected to the bore at a location downstream of the element, and a valve member is slidable within the bypass chamber, the valve member being so arranged that if the pressure applied to fluid upstream of the inlet to the chamber is such as to produce a constant rate of flow of the fluid or is increased, the member is urged in a direction downstream of the chamber and serves to close or partially close the outlet therefrom, whilst if the said pressure is reduced, the member is urged in a direction upstream of the chamber so that fluid can flow through the chamber in a direction from the outlet towards the inlet thereof.

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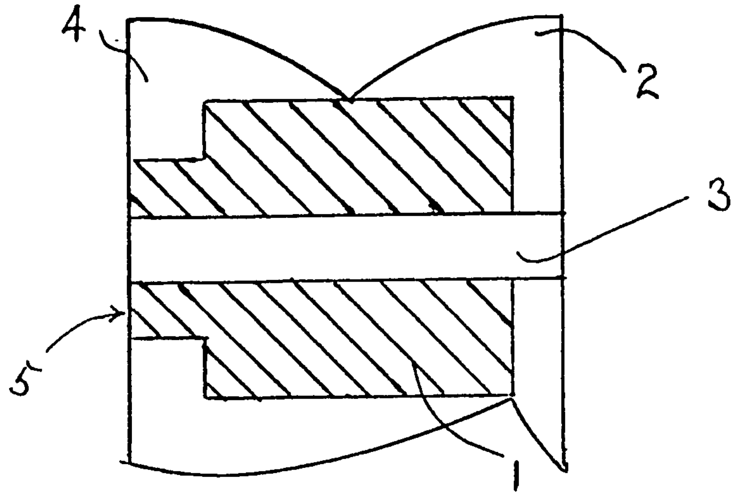

FIG. 1.

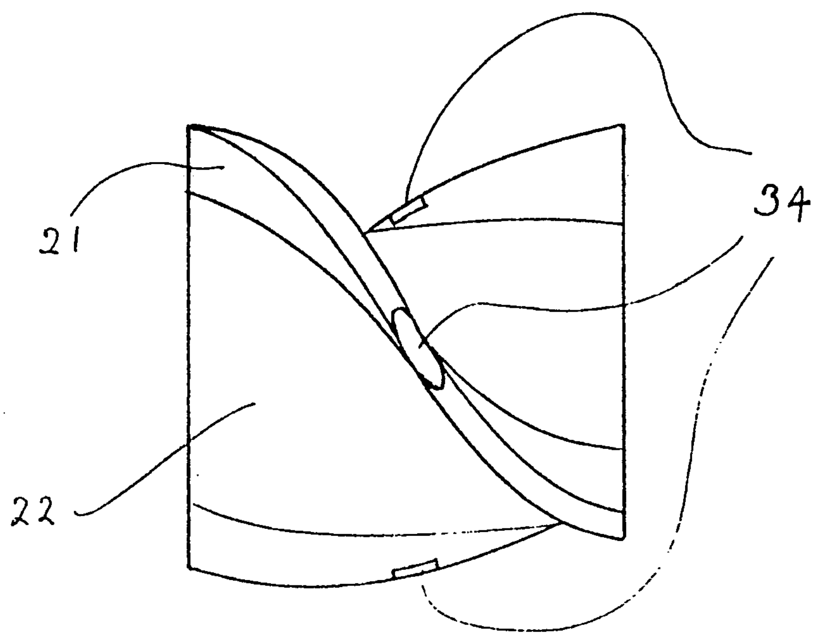

FIG. 2.

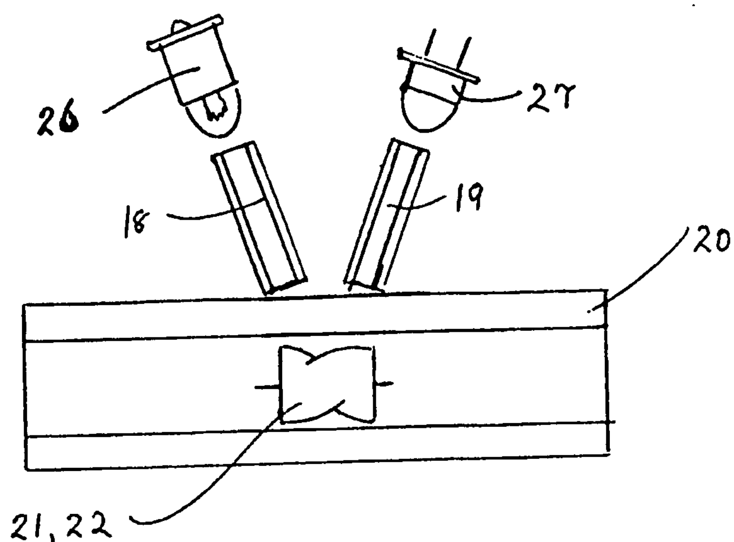

FIG. 3.

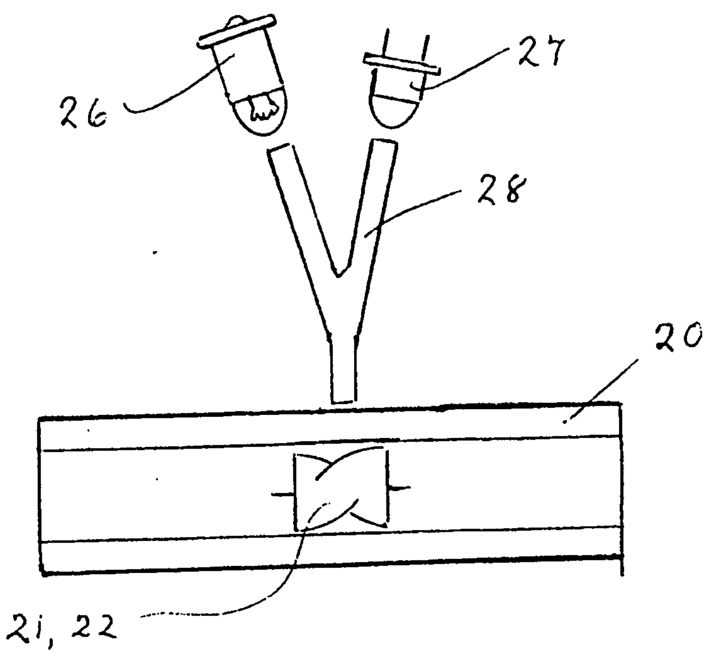

FIG. 4.

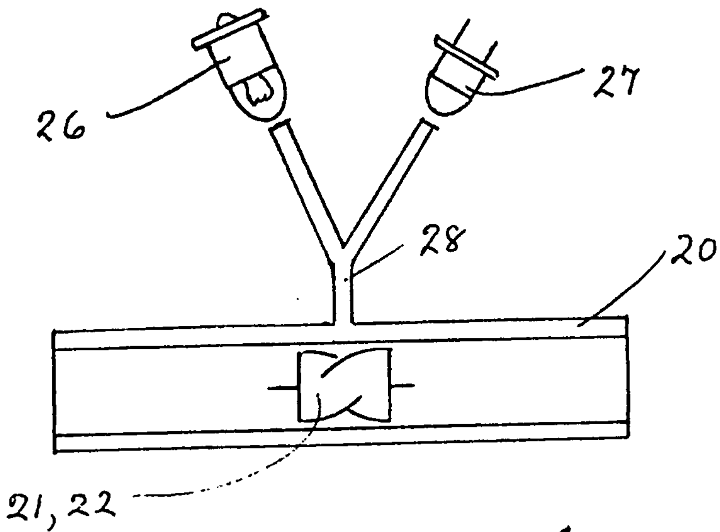

FIG. 6.

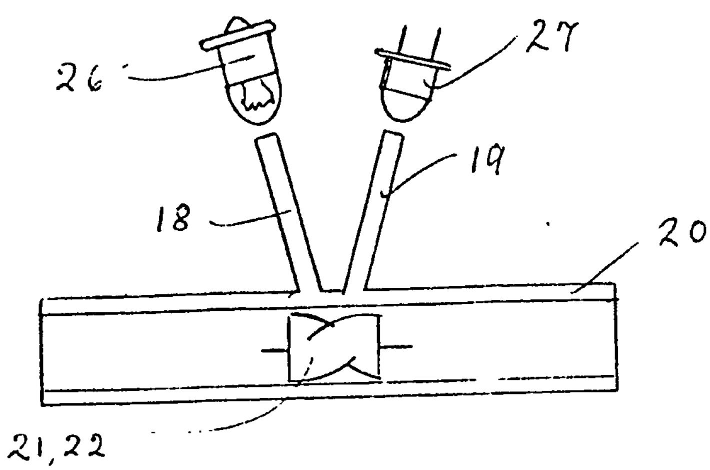

FIG. 5.

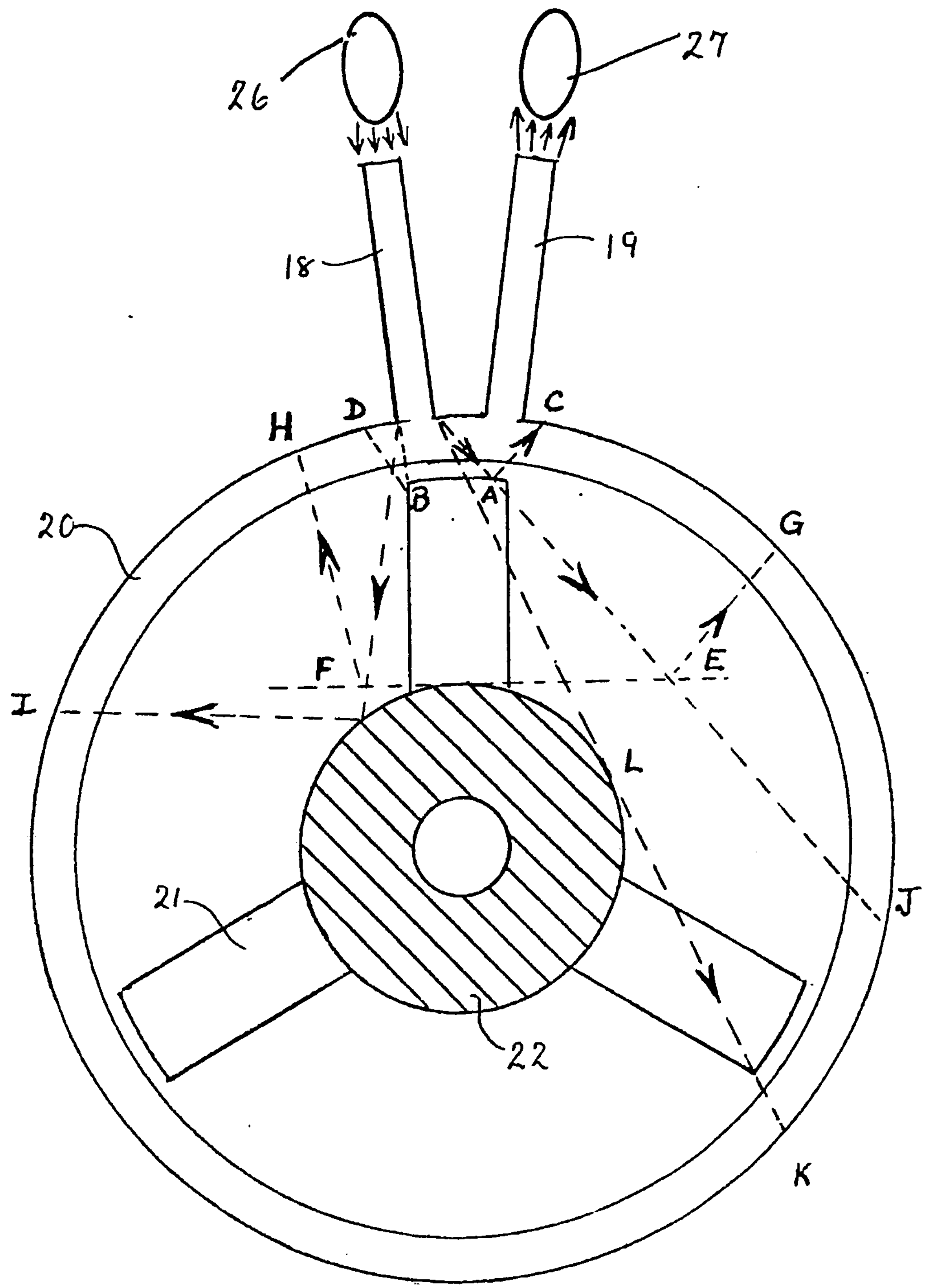

FIG. 7.

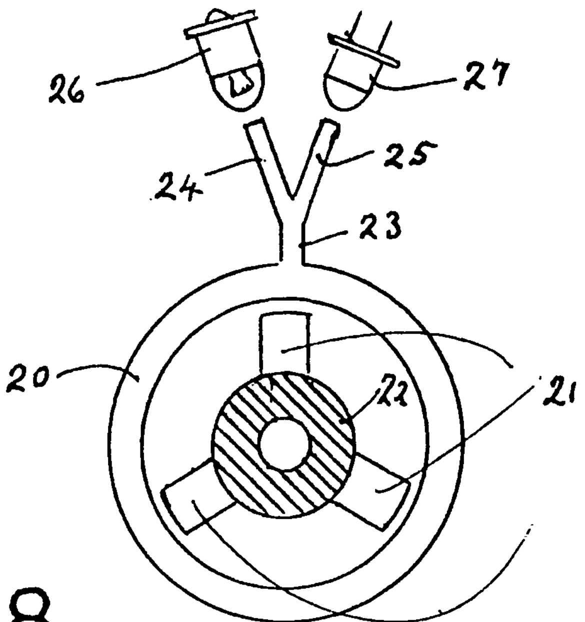

FIG. 8.

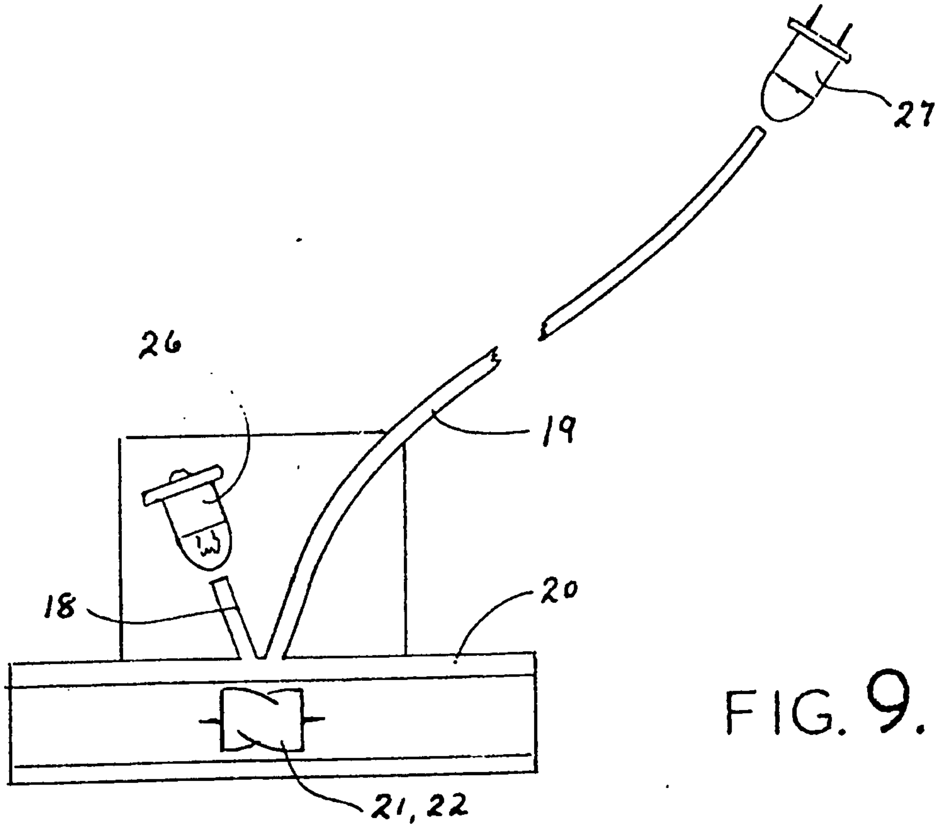

FIG. 9.

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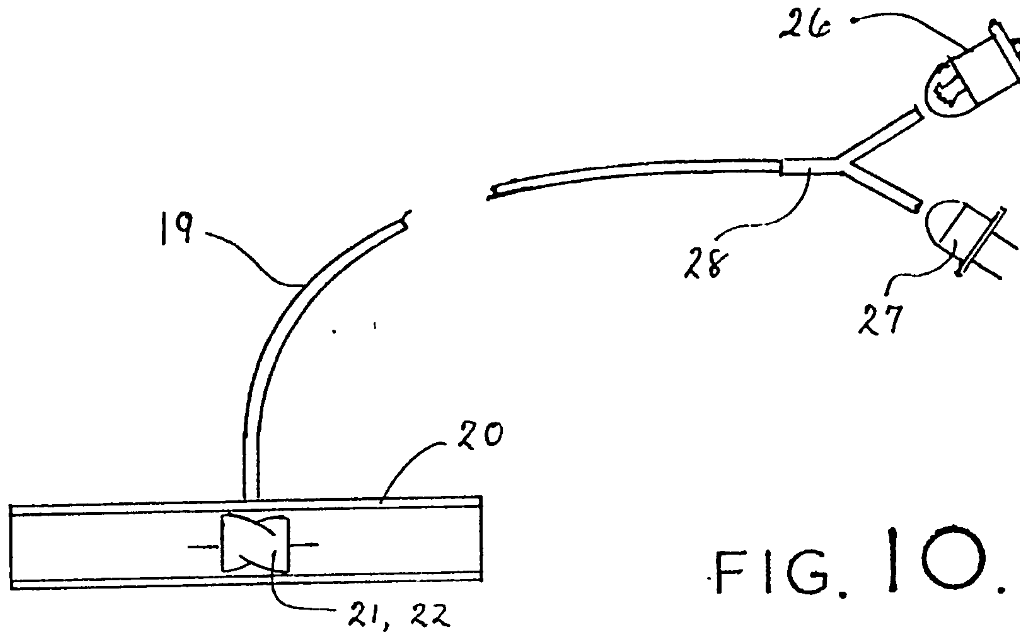

FIG. 10.

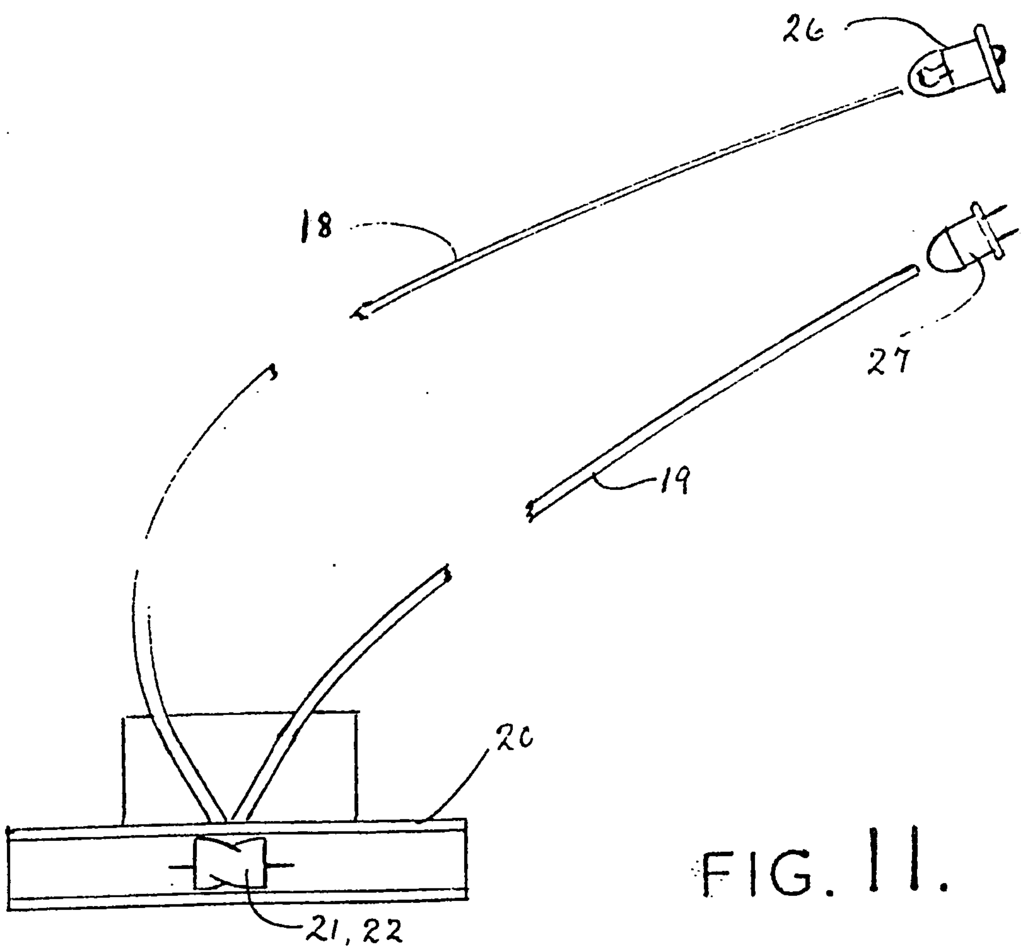

FIG. 11.

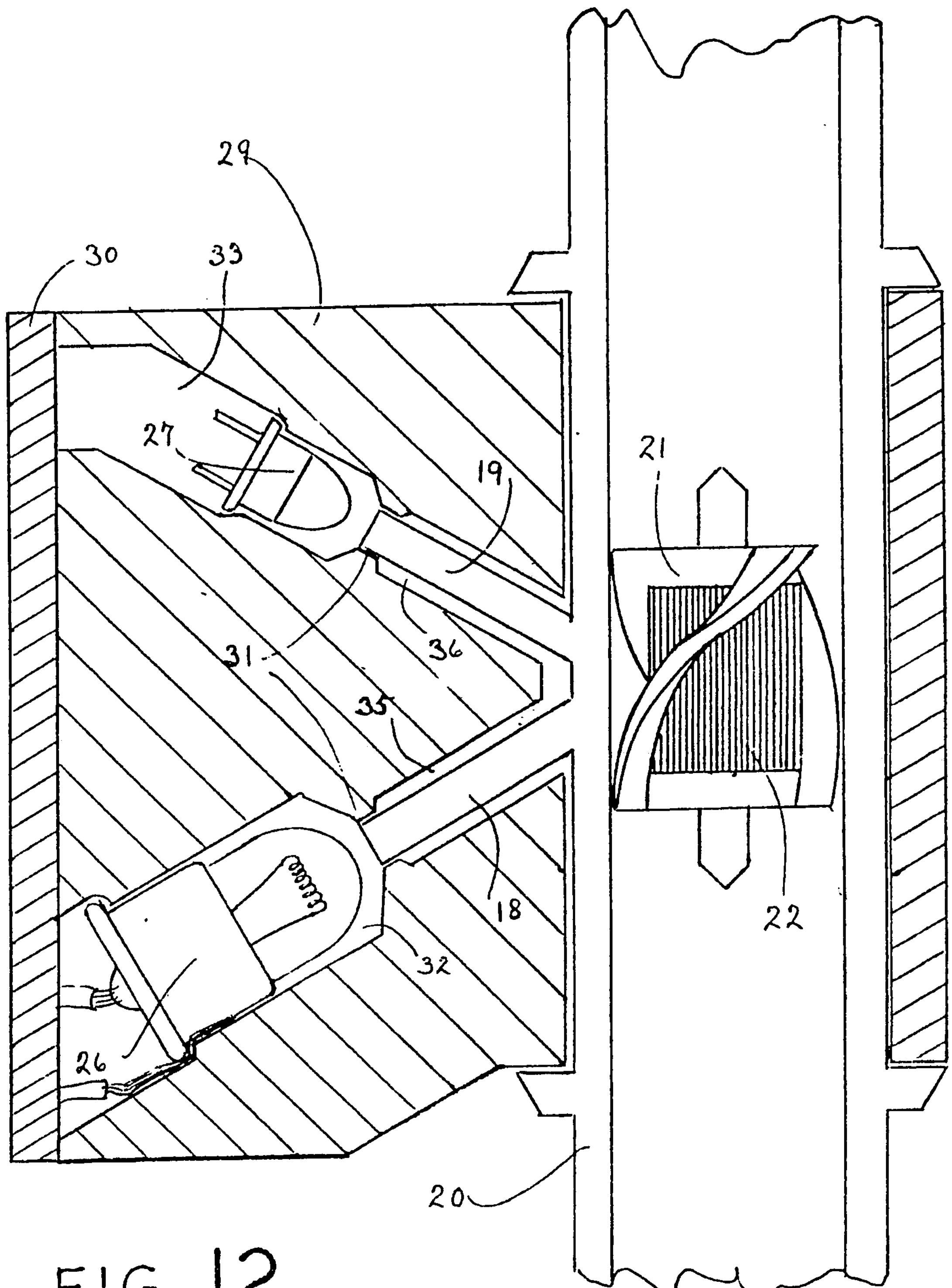

FIG. 12.

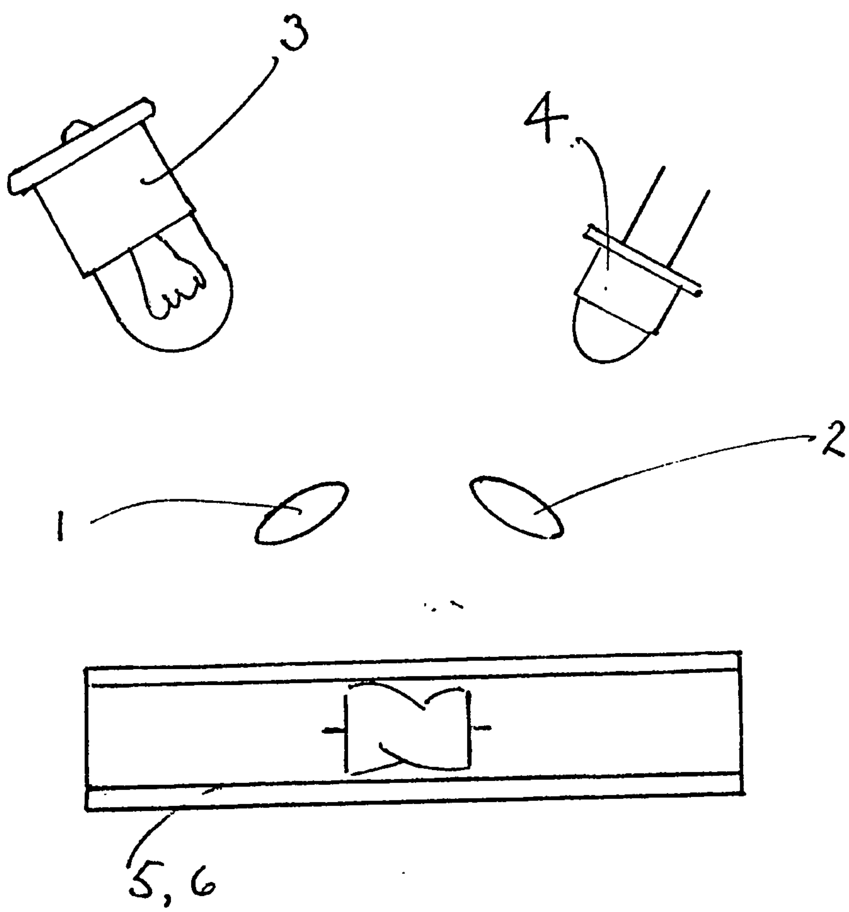

FIG. 13

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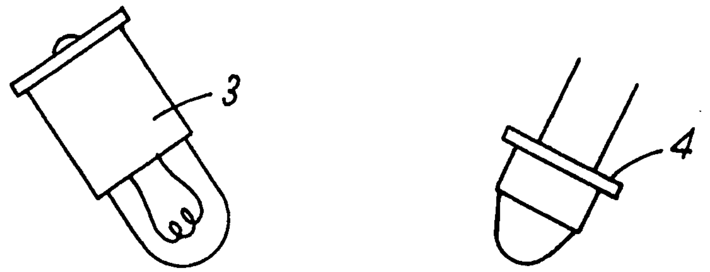

FIG.13

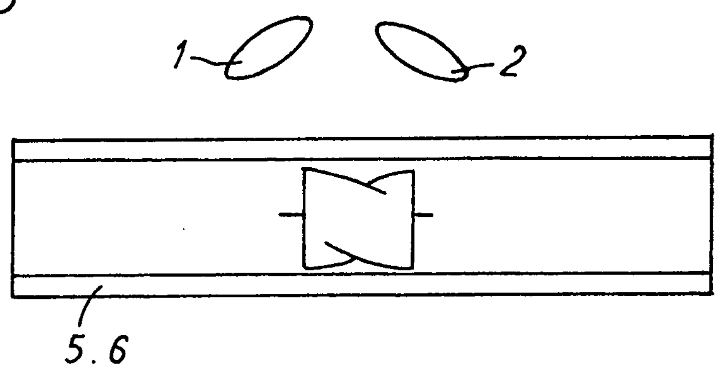

FIG.14

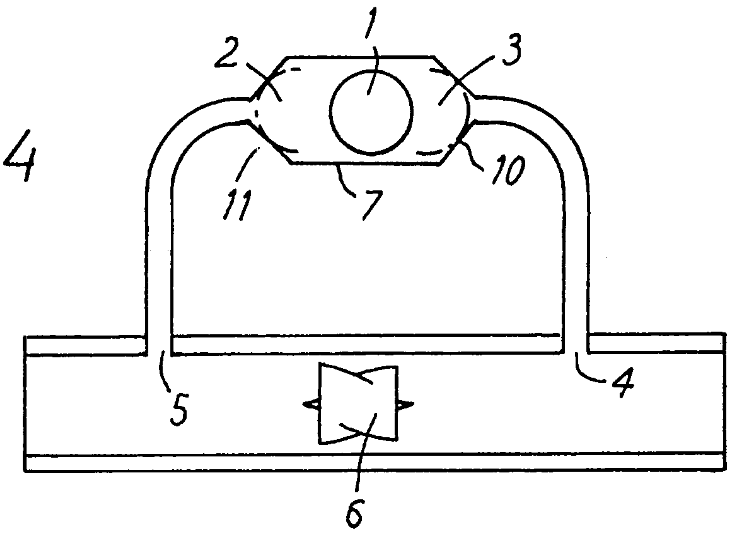

FIG.15

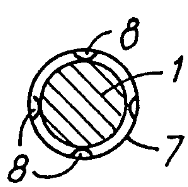

FIG.16

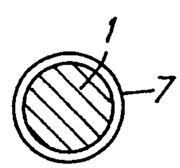

FIG.17